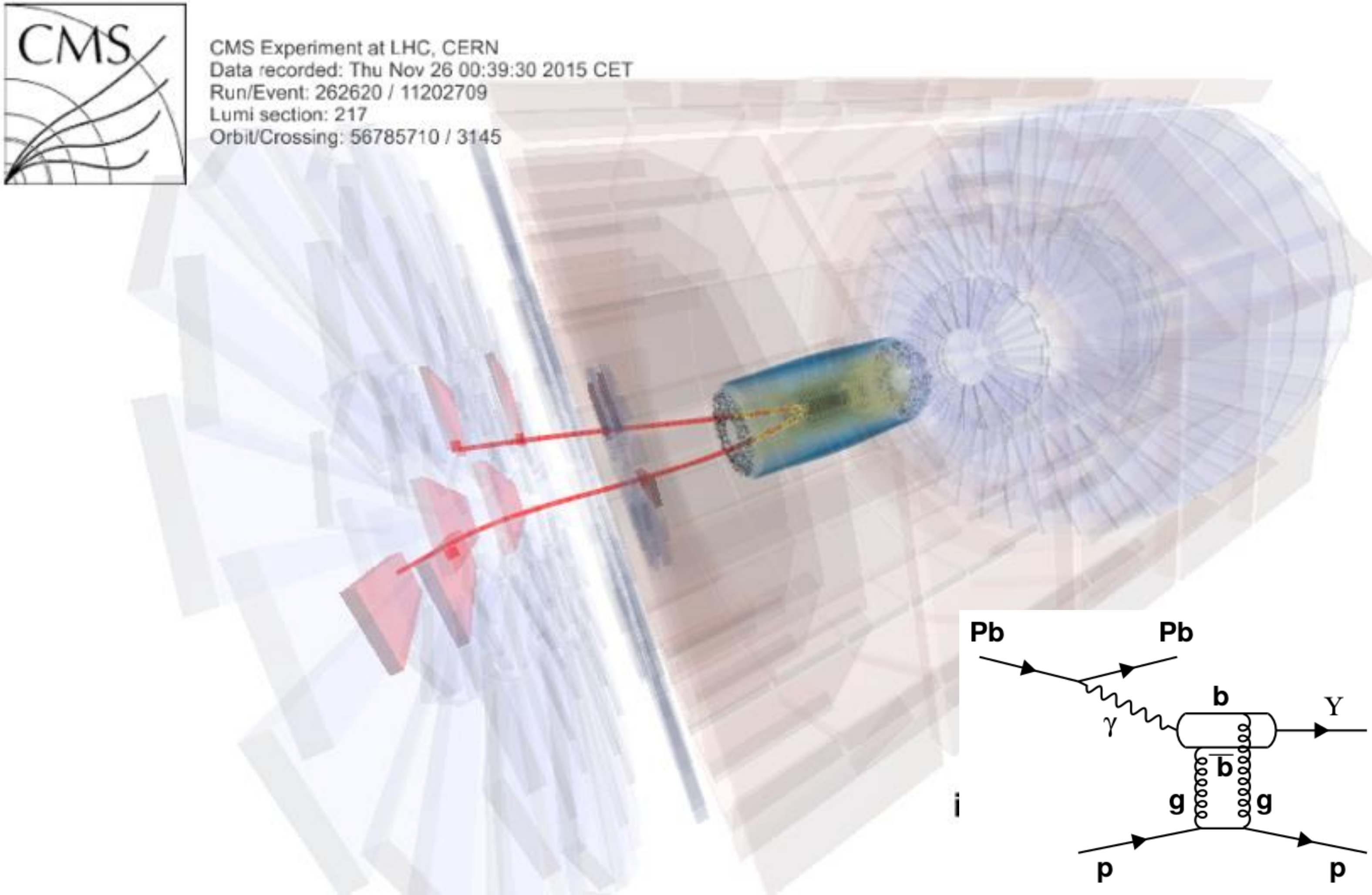
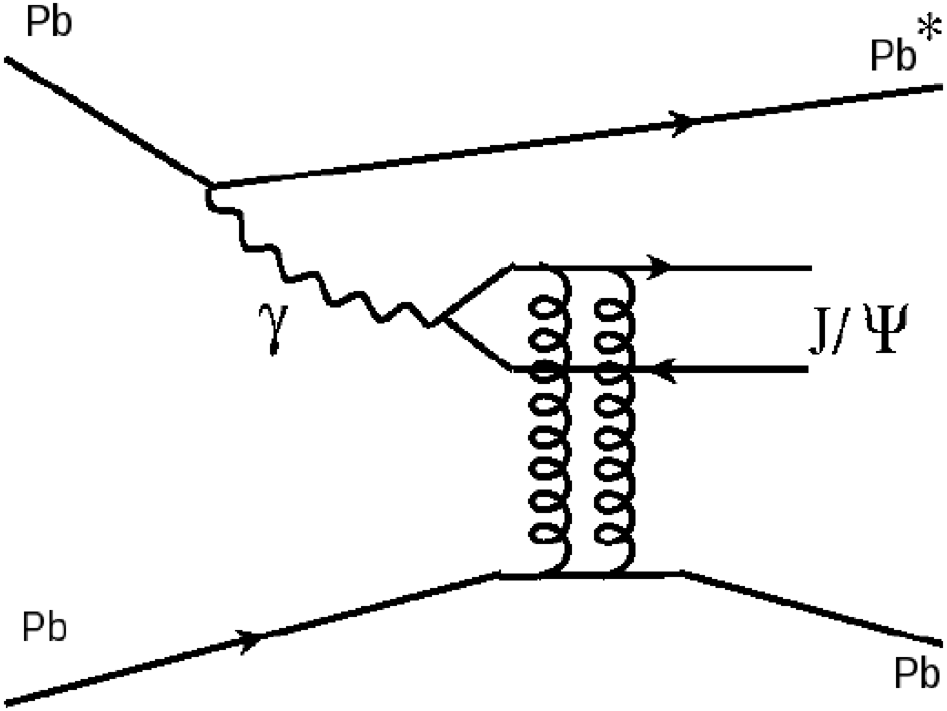
Ultra-peripheral results from CMS



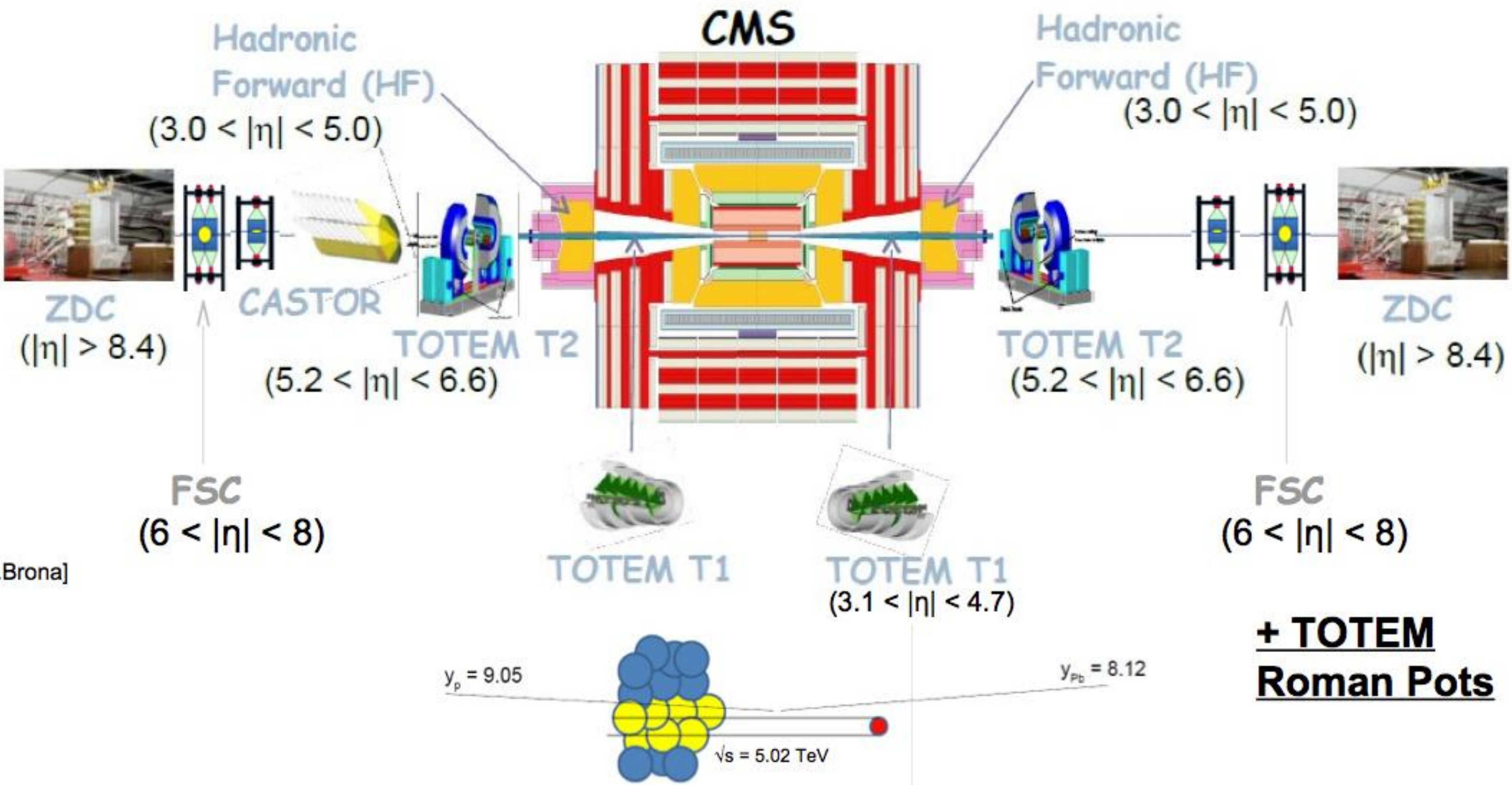
Vector meson photoproduction

$$\left.\frac{d\sigma_{\gamma A\to J/\Psi A}}{dt}\right|_{t=0} = \xi_{J/\Psi}\left(\frac{16\pi^3\alpha_s^2\Gamma_{l+l-}}{3\alpha M_{J/\Psi}^5}\right)[xG_A(x,\mu^2)]^2$$



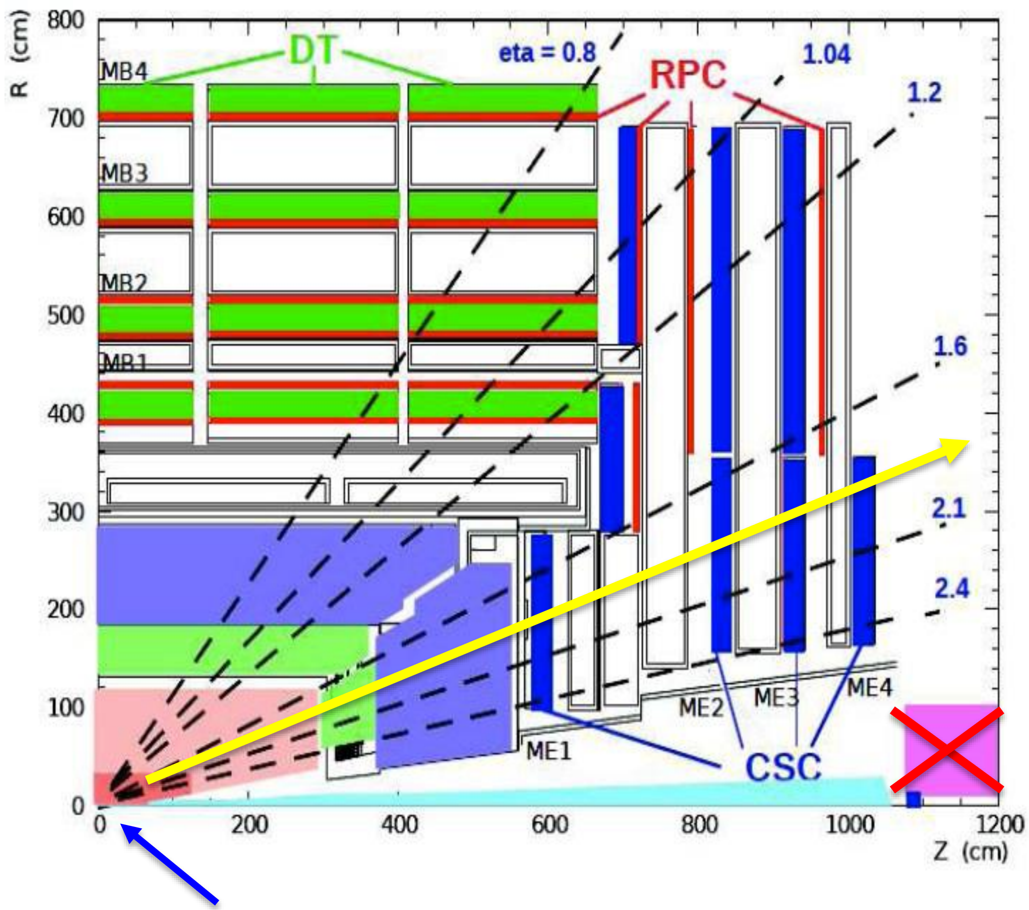
If wavelength of photon is comparable to size of nucleus we are sentive to the square of the average gluon density. If the wavelength is shorter then the cross section depends upon the sum of the squares of the gluon density in regions of the nucleus.

The Compact Muon Solenoid



[G.Brona]

Trigger requires 1 muon and 1 ZDC



μ

1 hit in muon chambers

Nothing in forward calorimeter

At least 1 forward neutron

At least 1 pixel track (HLT level)

Vector meson photoproduction in Pb-Pb

Total cross section

Low W: **x~ 10-2**

High W: **x~ 10-4**

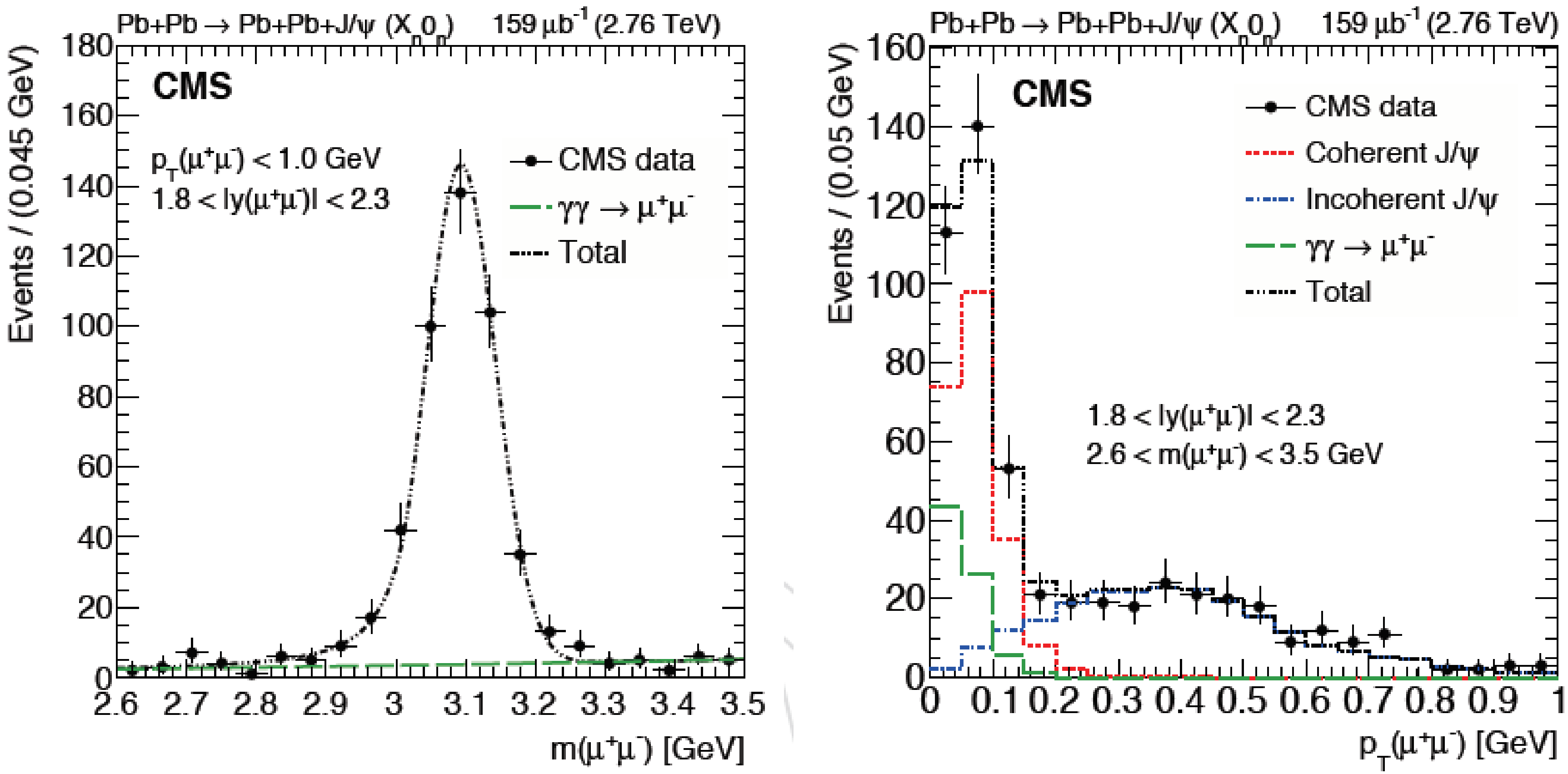
$$\frac{d\sigma_{\mathrm{PbPb}}(y)}{dy} = N_{\gamma/\mathrm{Pb}}(y,M)\sigma_{\gamma\mathrm{Pb}}(y) + N_{\gamma/\mathrm{Pb}}(-y,M)\sigma_{\gamma\mathrm{Pb}}(-y)$$

Neutron dependence

$$d\sigma(\mathrm{total})/dy = d\sigma(\mathrm{0n0n})/dy + 2d\sigma(\mathrm{0nXn})/dy + d\sigma(\mathrm{XnXn})/dy$$

Vector meson is accompanied by at least one neutron on one side of the interaction point and no neutron activity on the other side

Coherent J/ψ photoproduction



Coherent J/ψ photoproduction

$$\frac{d\sigma^{coh}_{X_n 0_n}}{dy}(\mathrm{J}/\psi) = \frac{N^{\mathrm{J}/\psi}_{coh}}{BR(\mathrm{J}/\psi \rightarrow \mu^+\mu^-) \cdot \mathcal{L}_{int} \cdot \Delta y \cdot (A \times \varepsilon)^{\mathrm{J}/\psi}}$$

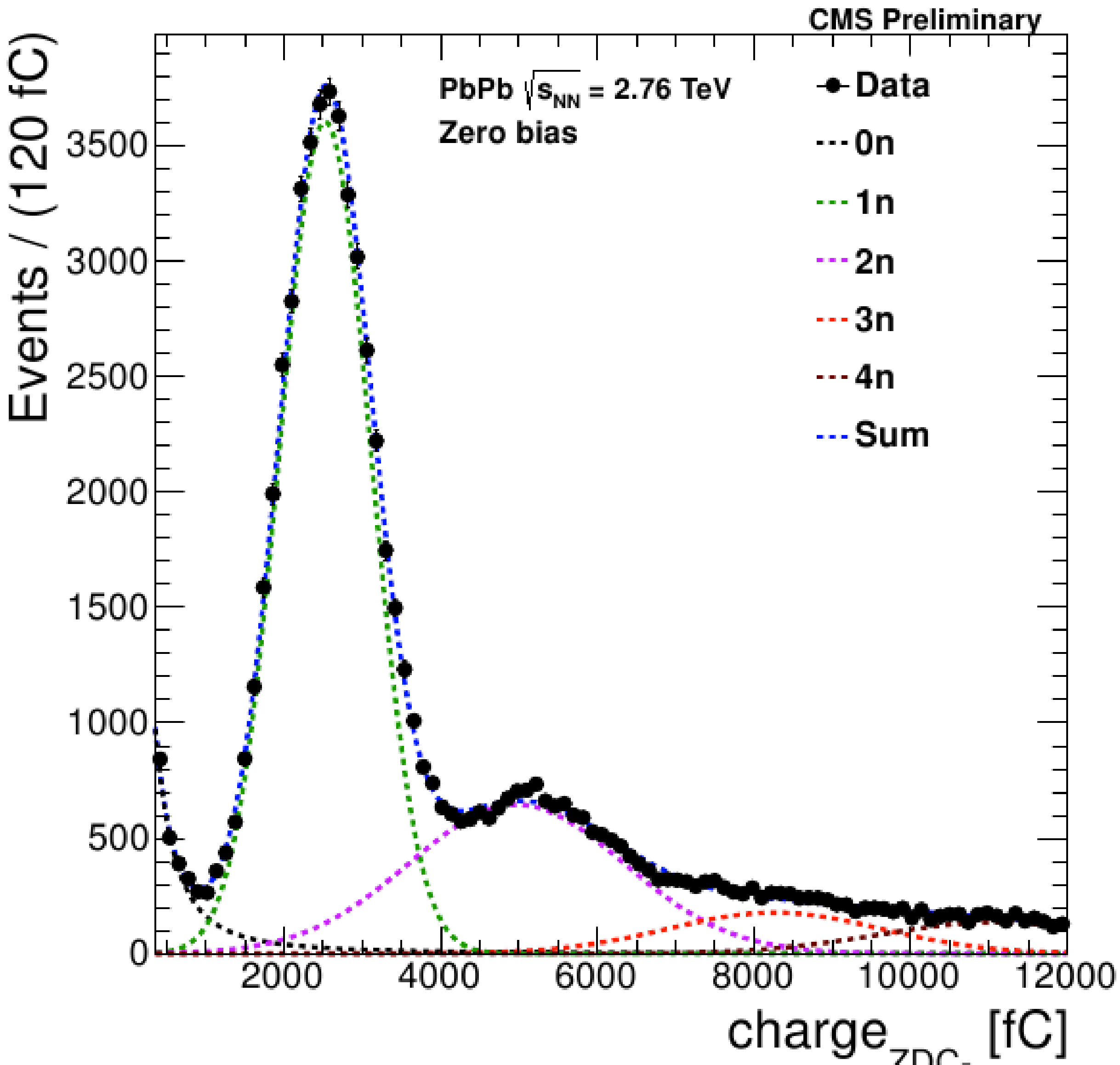
- The acceptance and reconstruction efficiency are estimated from MC and found to be 12%

- The trigger efficiency is measured from data and found to be 50%

Coherent J/ψ photoproduction
Systematic uncertainties

Source	Uncertainty
(1) Signal extraction	5%
(2) Neutron tagging	6%
(3) HF energy limit	2%
(4) MC acceptance corrections	1%
(5) ZDC efficiency estimation	3%
(6) Tracking reconstruction	4%
(7) Int. luminosity determination	5%
(8) Branching fraction	1%
Total	11%

Identifying neutrons with the ZDC



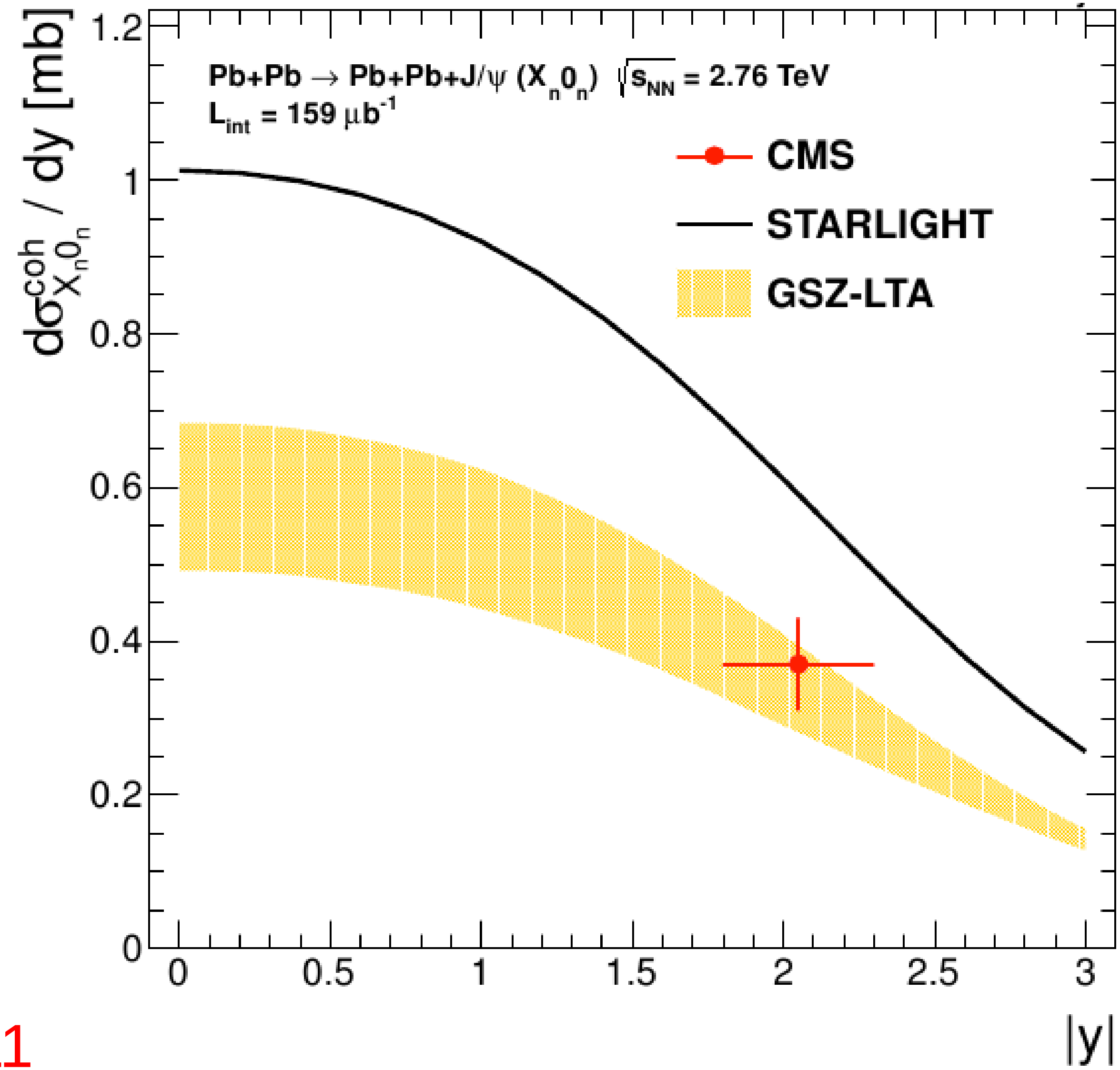
Thresholds are set from minimum bias data

Break-up modes for UPC J/ψ

Xn0n single-sided with any number of neutrons
XnXn double-sided with any number of neutrons on either side
1n1n double-sided with only one neutron on each side

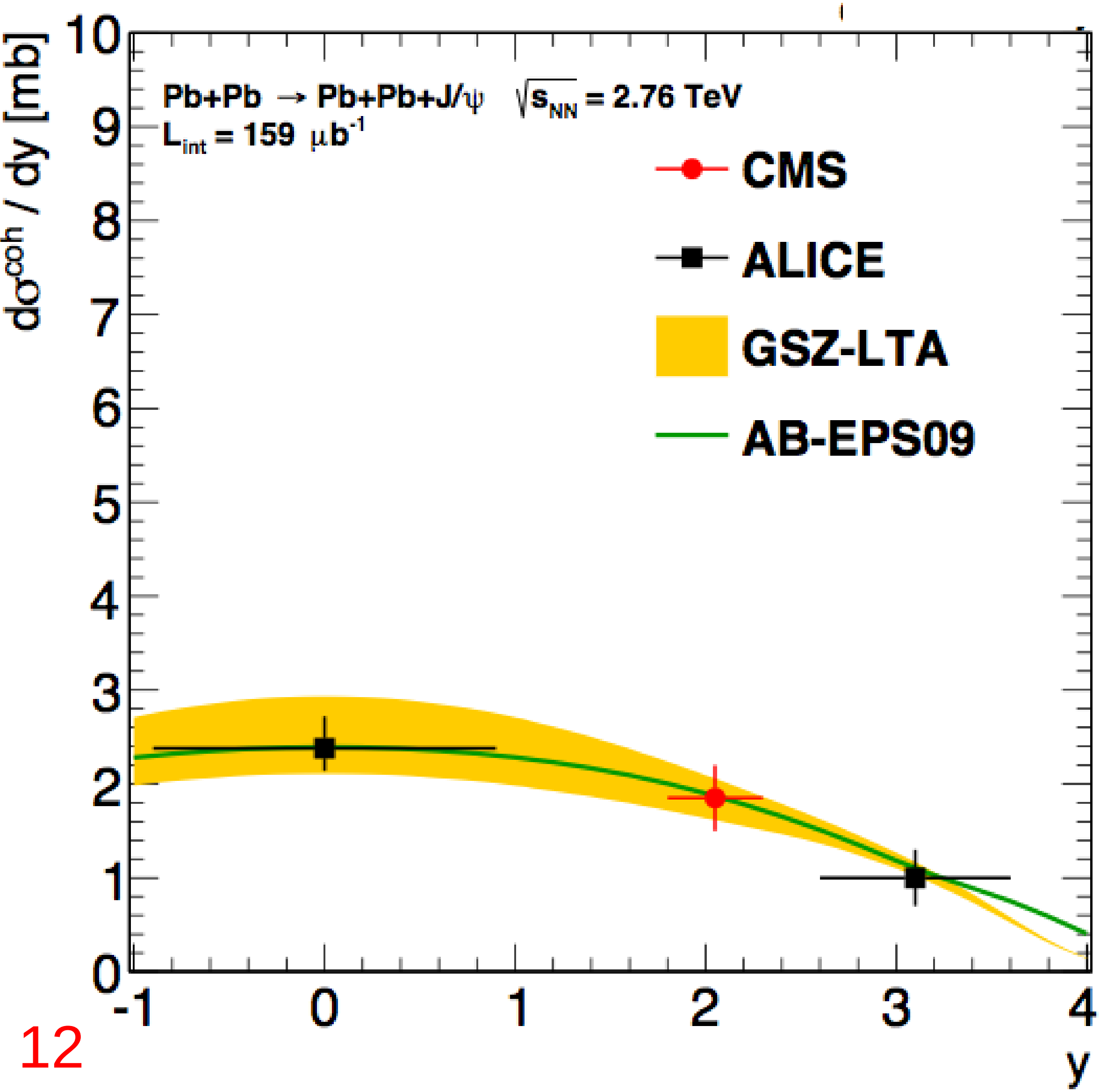
J/ψ with p_T <0.15 GeV/c	X_nX_n/X_n0_n	$1_n0_n/X_n0_n$	$1_n1_n/X_n0_n$
Data	0.36±0.04	0.26±0.03	0.03±0.01
STARLIGHT	0.37	N/A	0.02
GSZ	0.32	0.30	0.02

UPC PbPb => J/ψ + neutrons



$X_n 0_n$ is the dominant mode that has neutron emission

Coherent J/ψ photoproduction

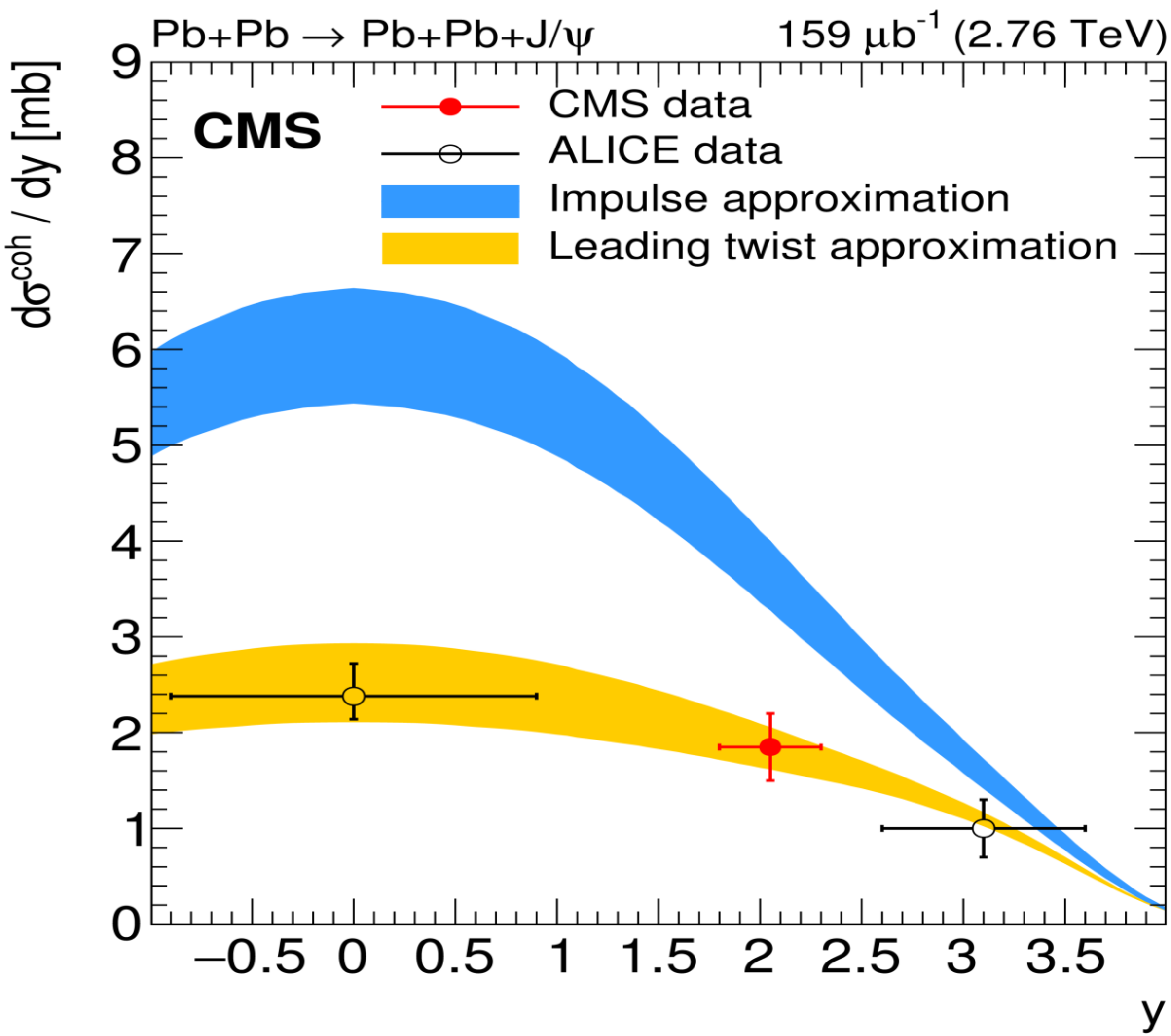


Eur. J. Phys. C73, 2617 (2013)

CMS-PAS-HIN-12-009 (2014)

CMS result for Xn0n is scaled up to the total cross section with STARLIGHT.

Rapidity distribution of coherent J/ψ

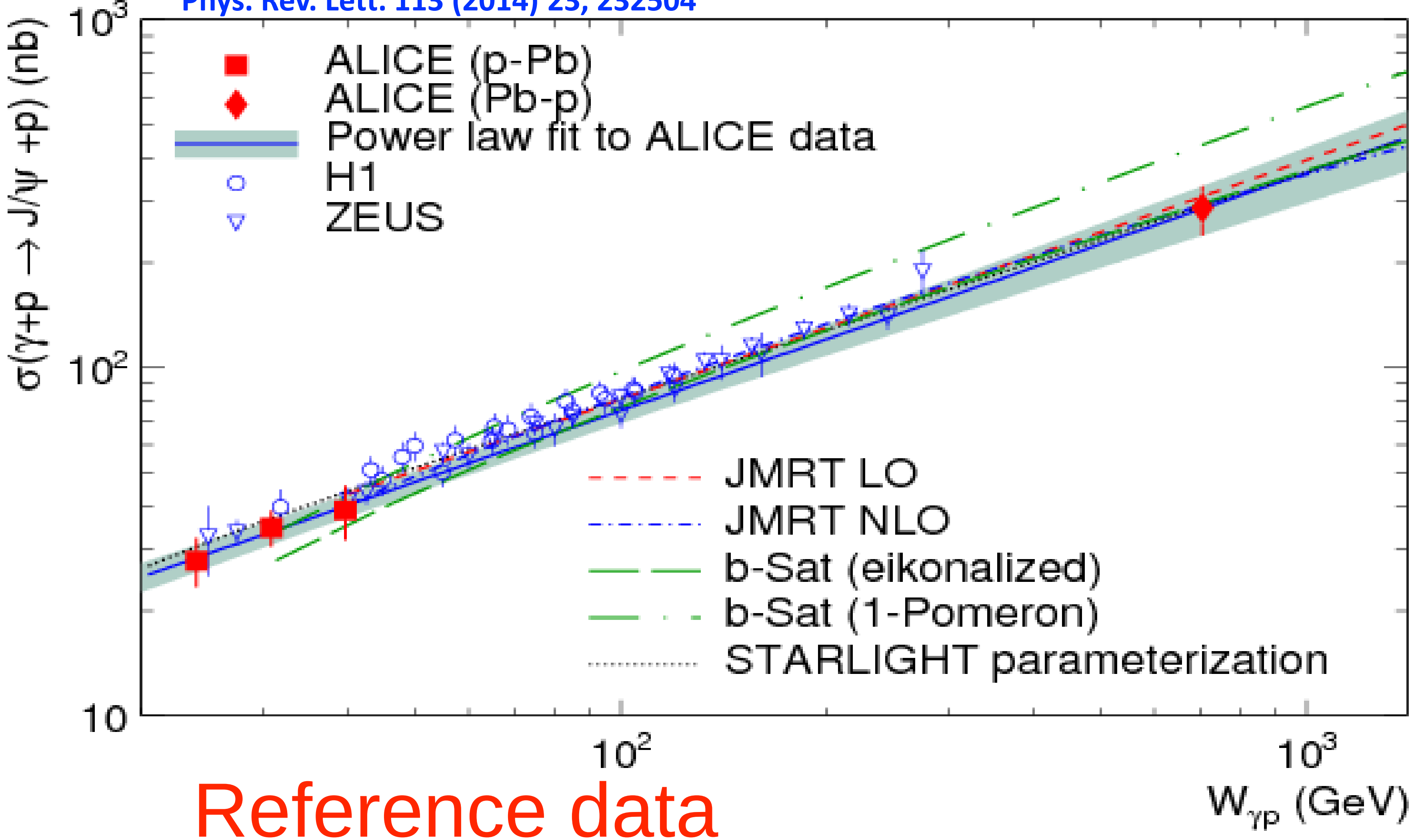


http://arxiv.org/abs/1605.06966v1

CMS-HIN-12-009

J/ψ versus γp center of mass energy

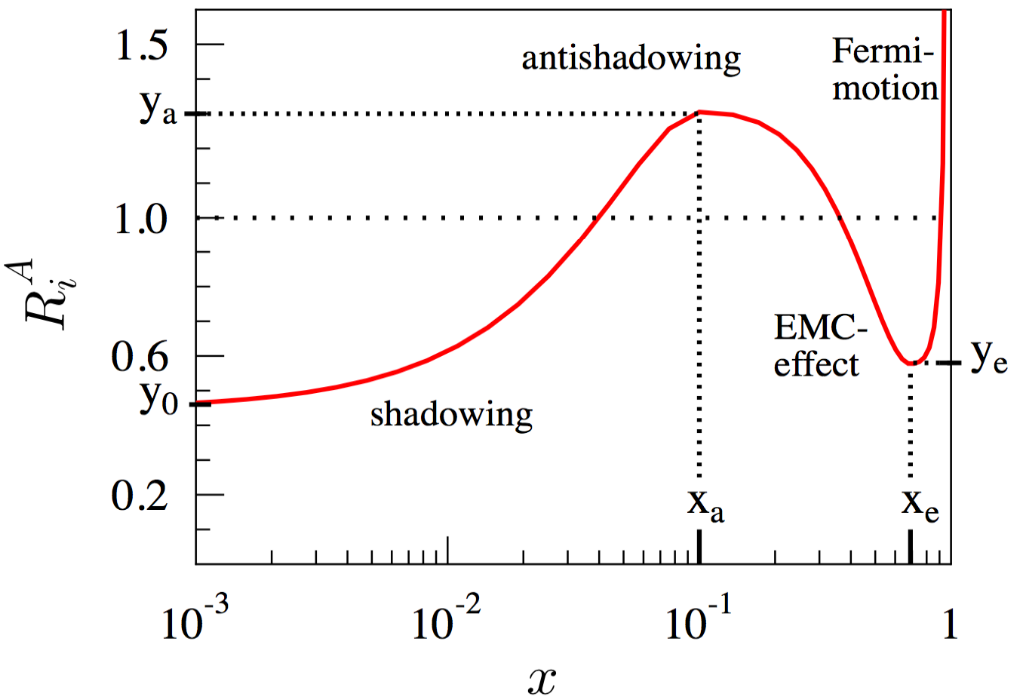
Phys. Rev. Lett. 113 (2014) 23, 232504

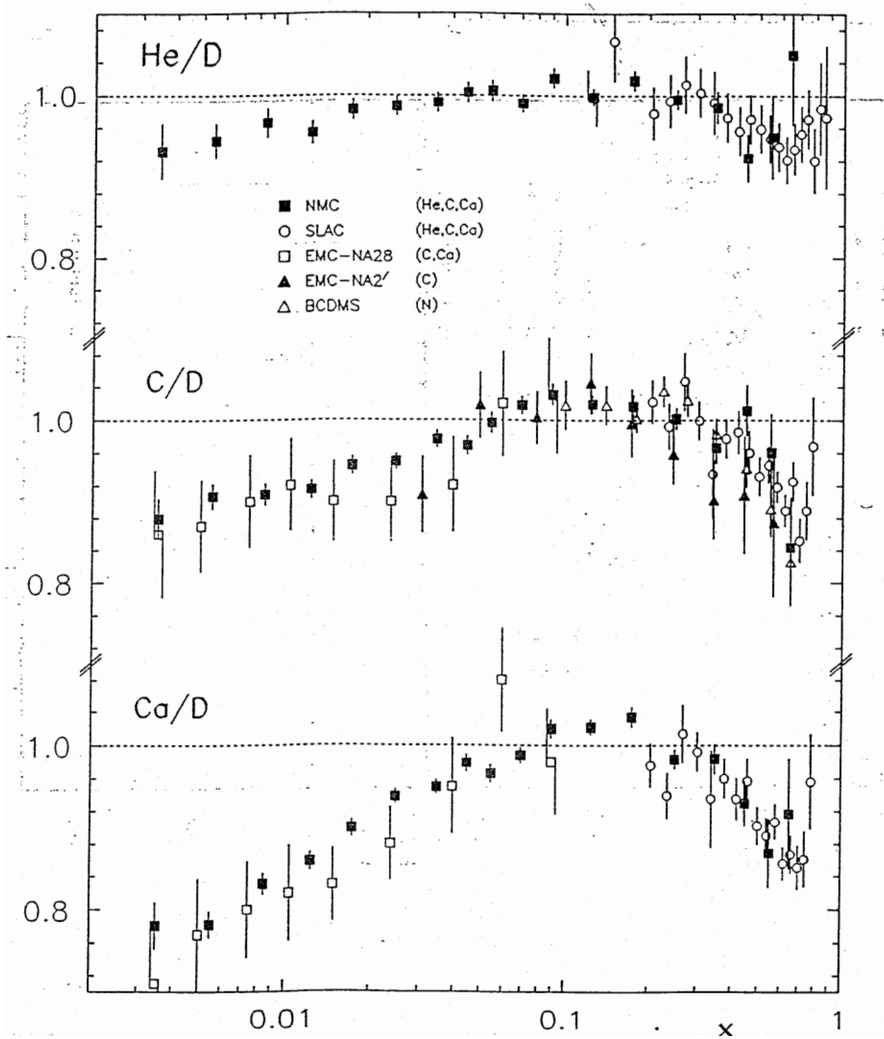


Reference data

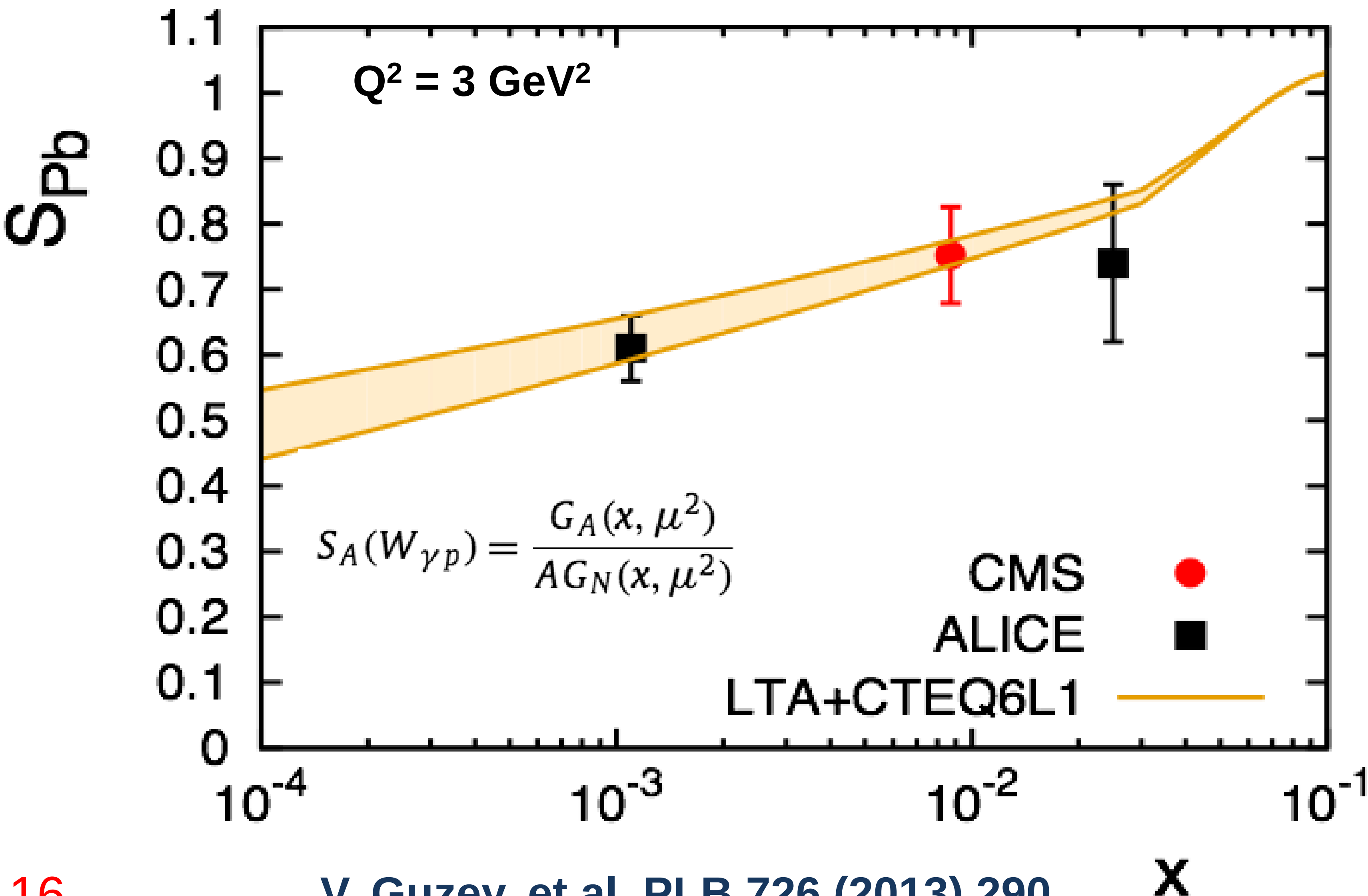
for J/Ψ in γ+Pb results

Models of Nuclear effects





Nuclear gluon density



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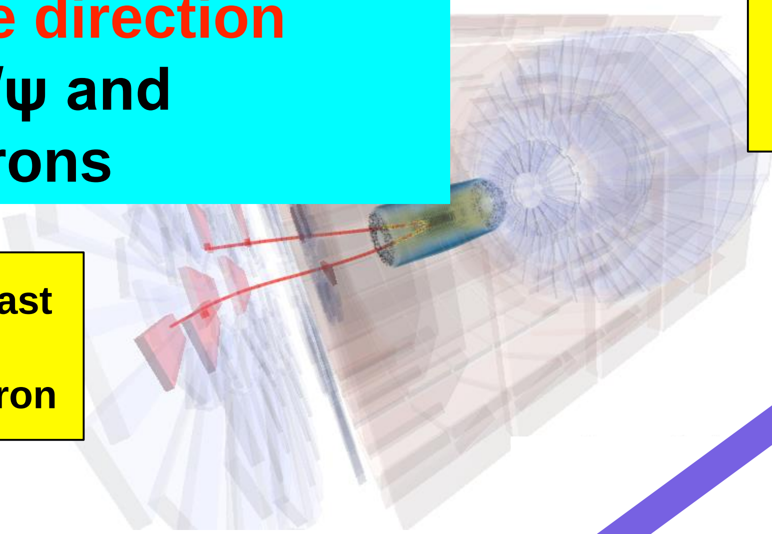
Two different topologies

Same direction for J/ψ and neutrons

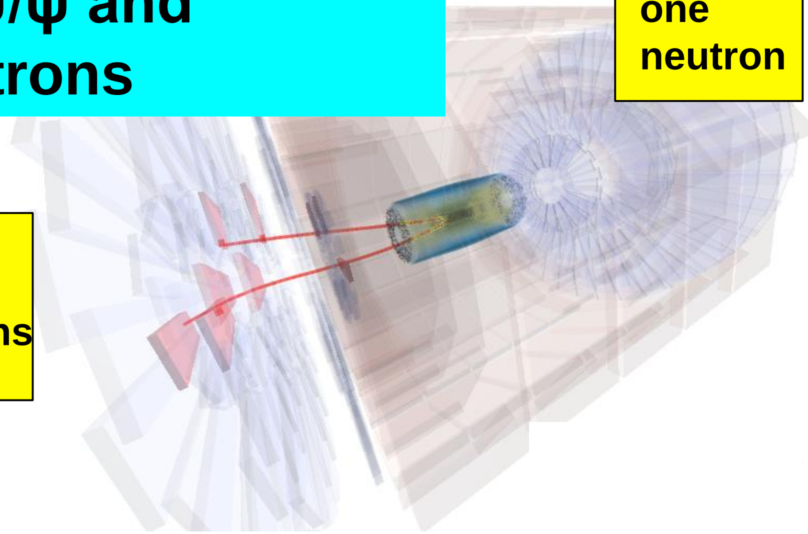


No neutron

At least one neutron

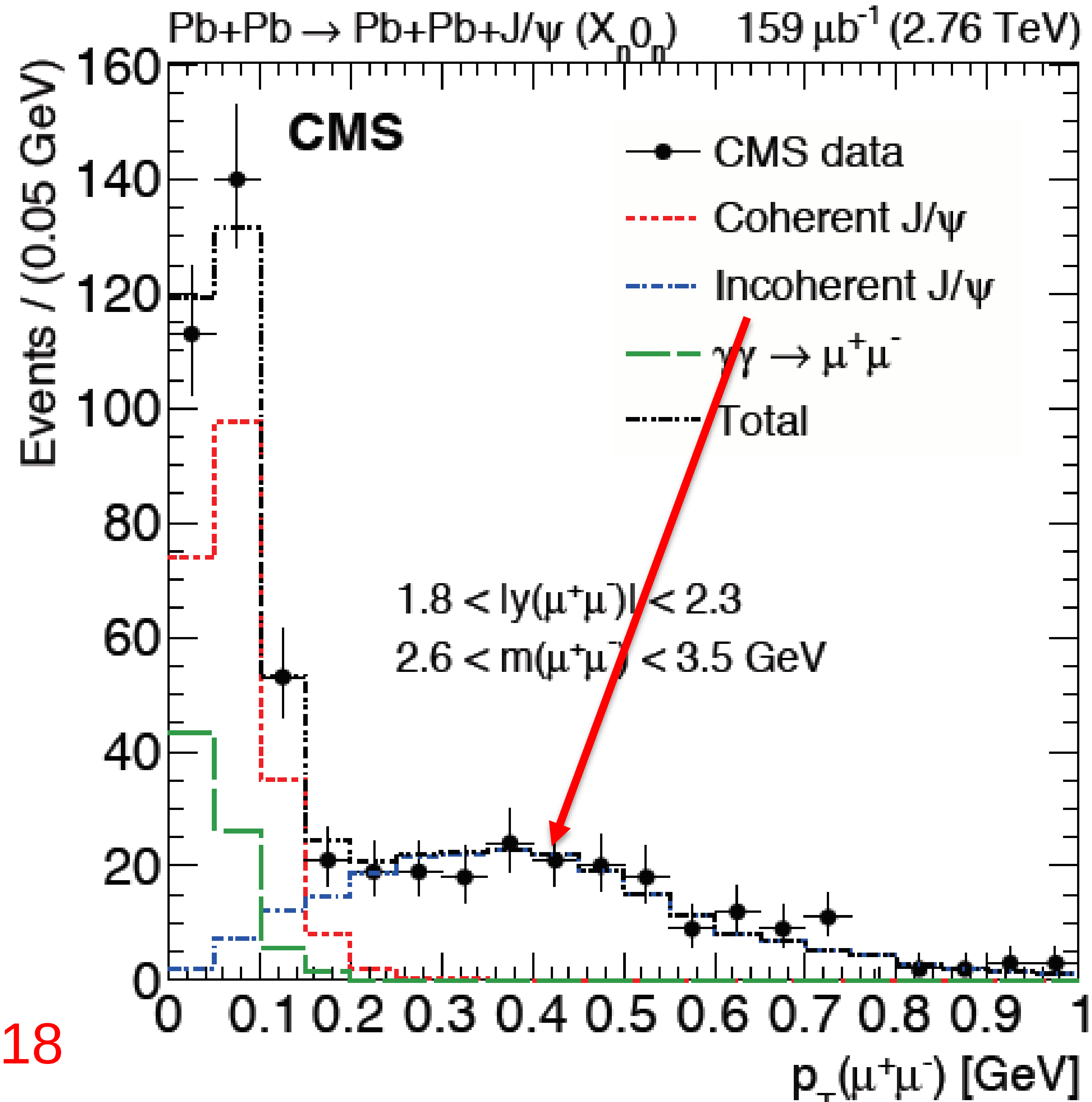
Opposite direction for J/ψ and neutrons

At least one neutron



No neutrons

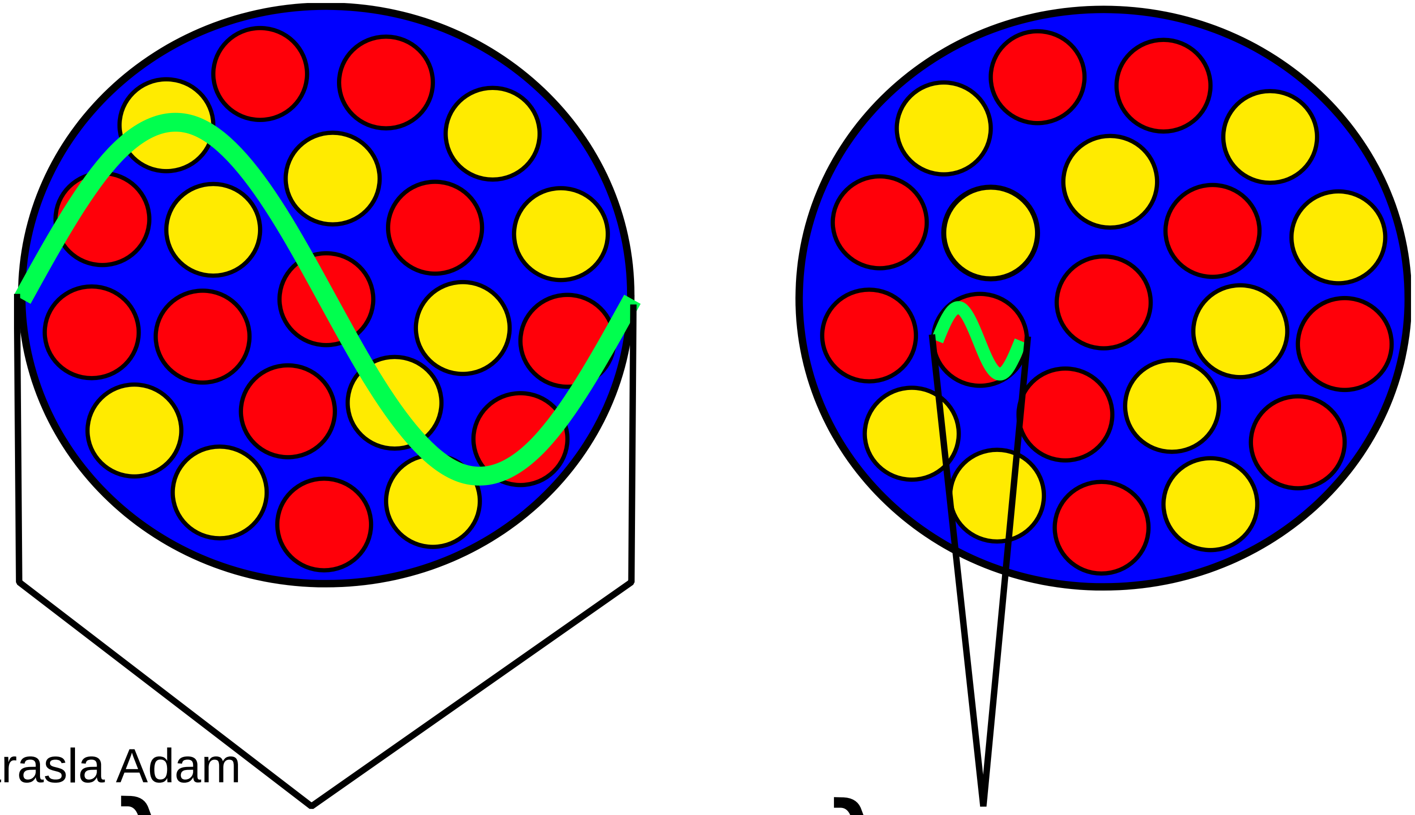
Incoherent J/ψ for p_T > 150 MeV/c



Incoherent J/ψ (Xn0n):
Almost all events are in the High-x region.

At Low-x, incoherent production is very strongly suppressed wrt to High-x region - First time seen in γ+Pb interactions

Can we measure fluctations



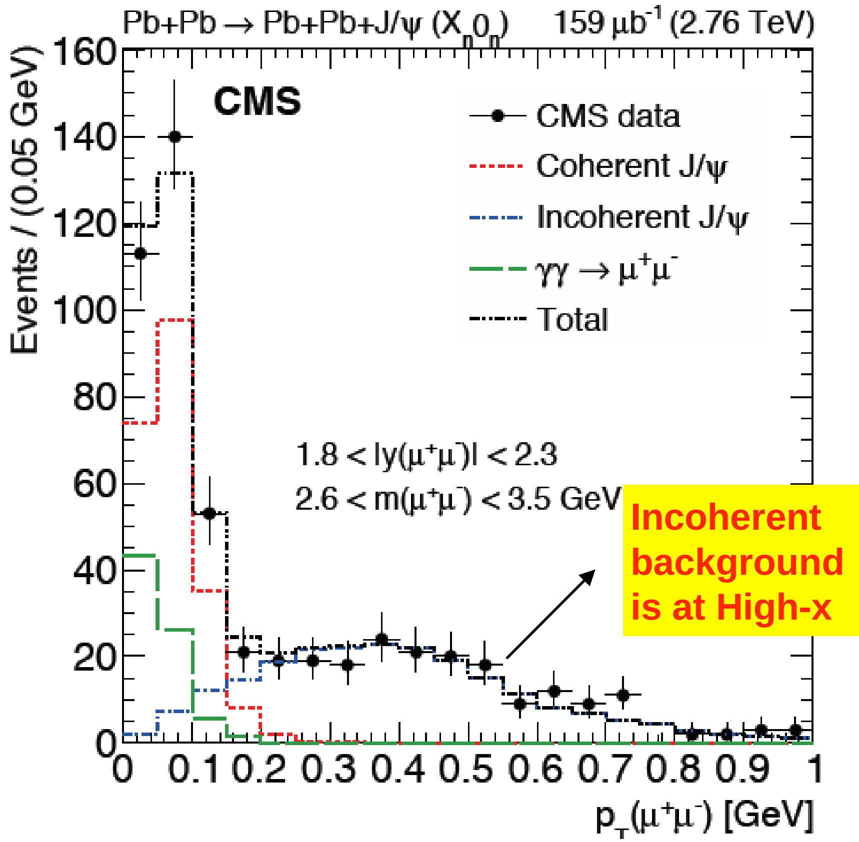
Jarasla Adam

$\lambda_{\text{Coherent}}$ $\lambda_{\text{Incoherent}}$

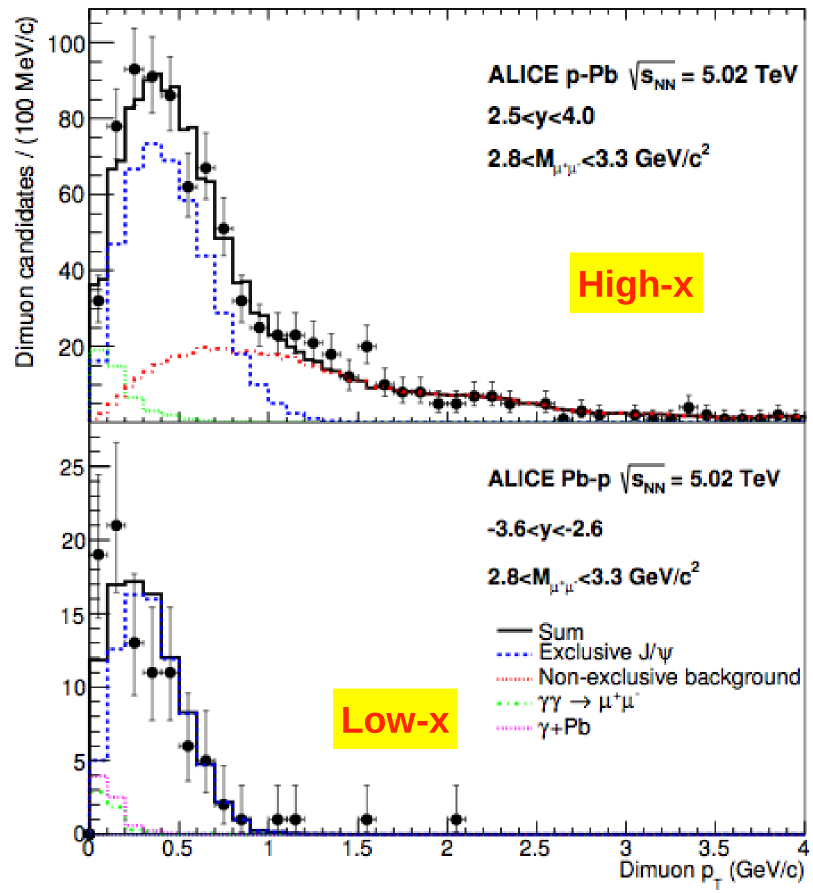
$\boldsymbol{\sigma}_{coh}$ proportional to (avearge gluon density) $\boldsymbol{\sigma}_{incoh}$ proportional to $\Sigma\ g_i^2$

Comparison of γ+Pb to γ+p

γ+Pb



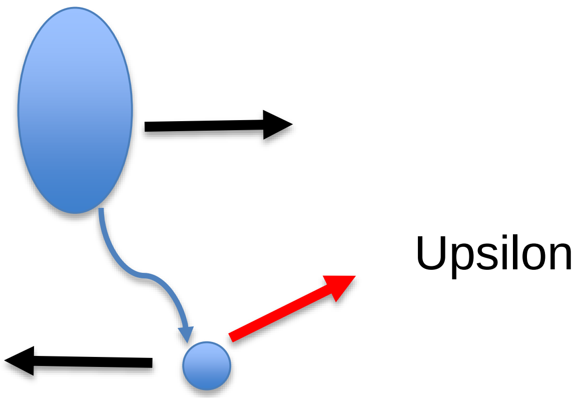
γ+p

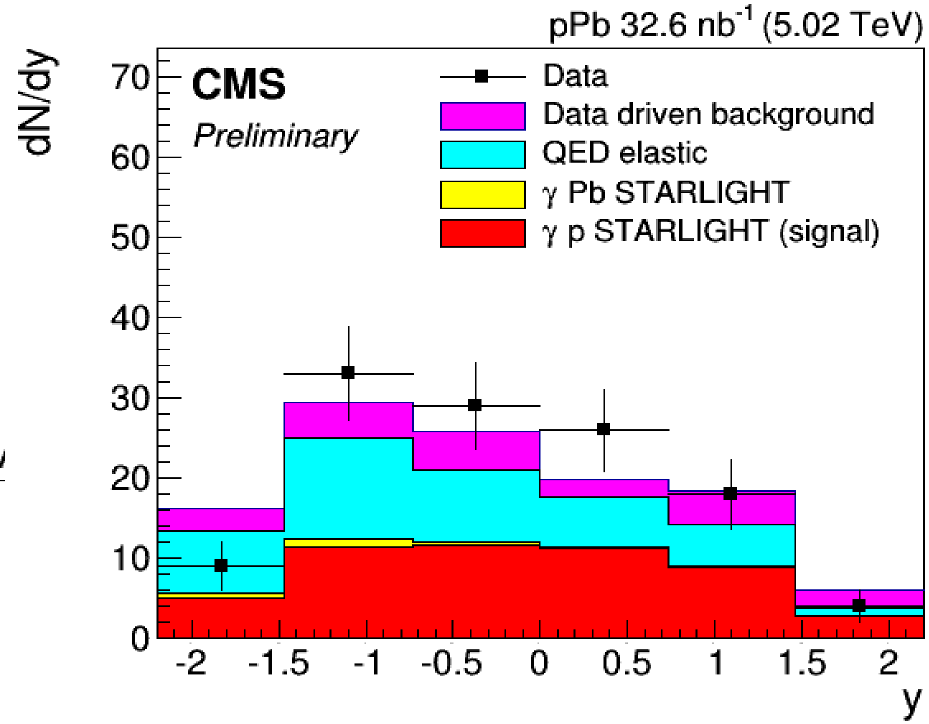


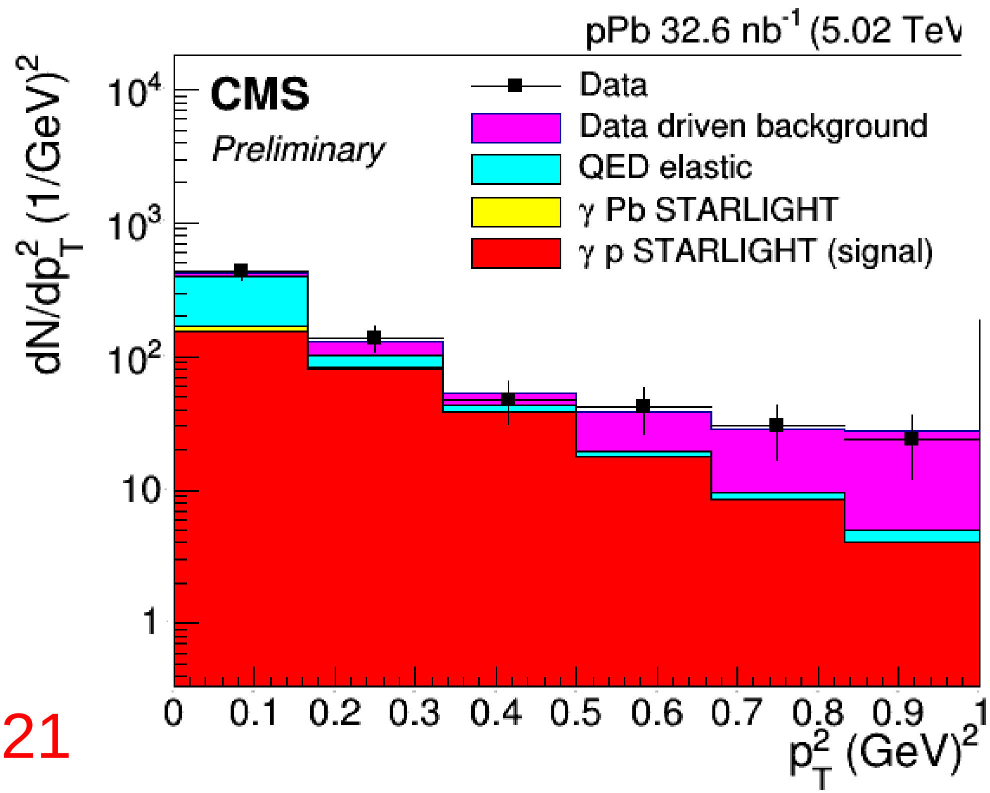
Events are in the High-x region. ***At Low-x incoherent yield is heavyily suppressed***

ALICE PRL 113 (2014) 23, 232504, see also J. Cepina et al. PLB 766 (2017) 186-191

pPb => Exclusive Υ at $\sqrt{s_{NN}}$ = 5.02 TeV

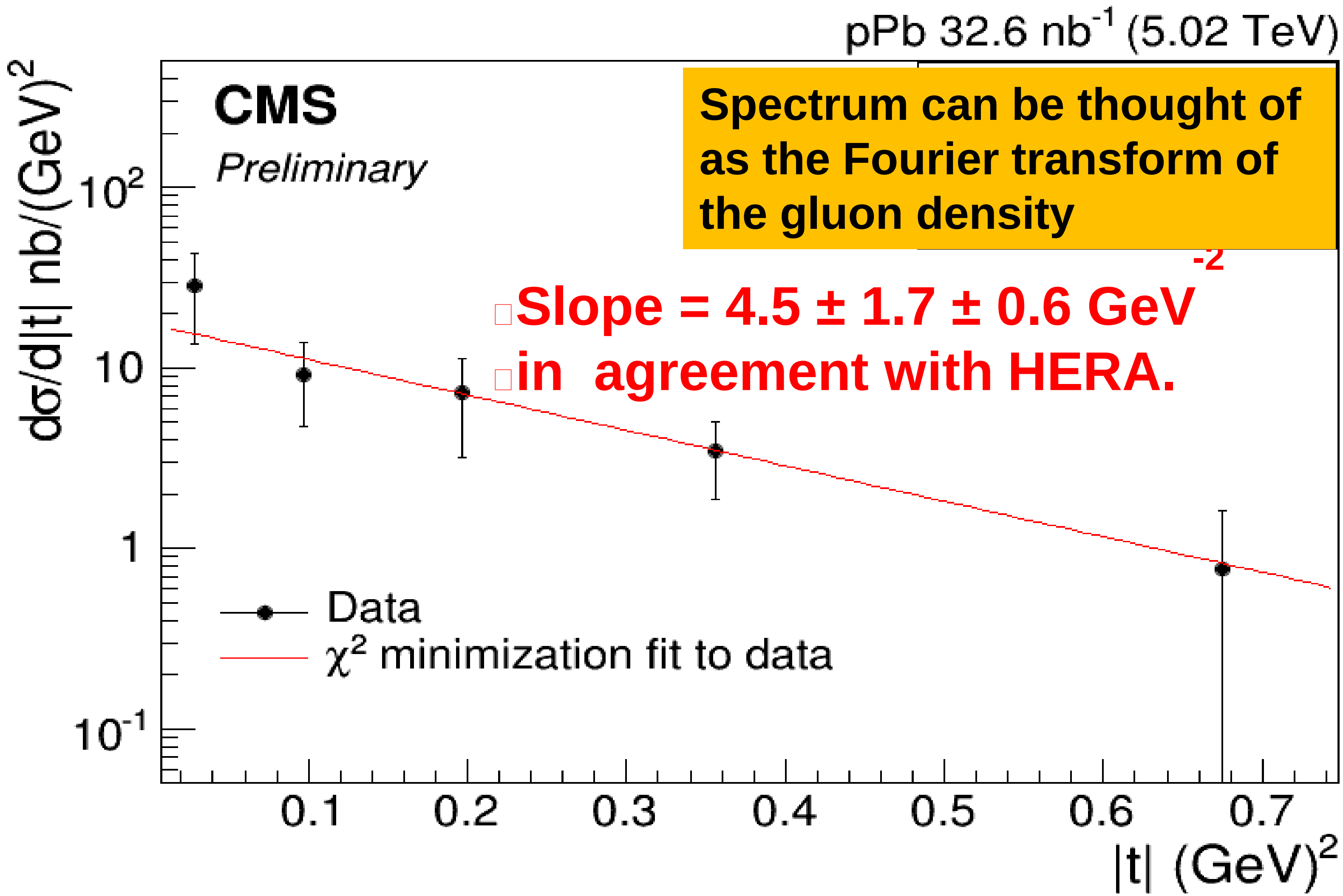






CMS-FSQ-13-009

Exclusive Υ vs p_T^2



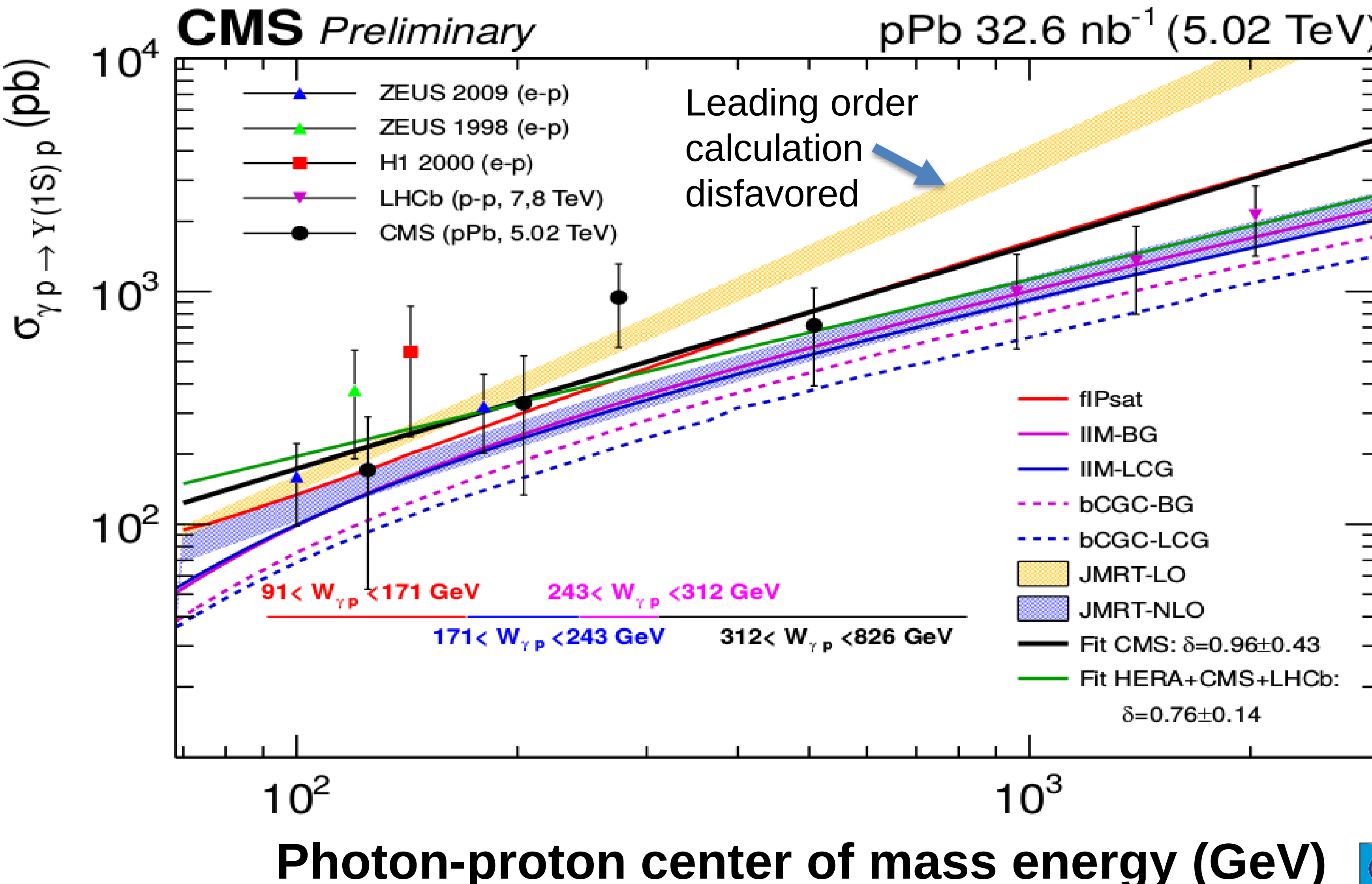
Spectrum can be thought of as the Fourier transform of the gluon density

Slope = 4.5 ± 1.7 ± 0.6 GeV^{-2}

in agreement with HERA.

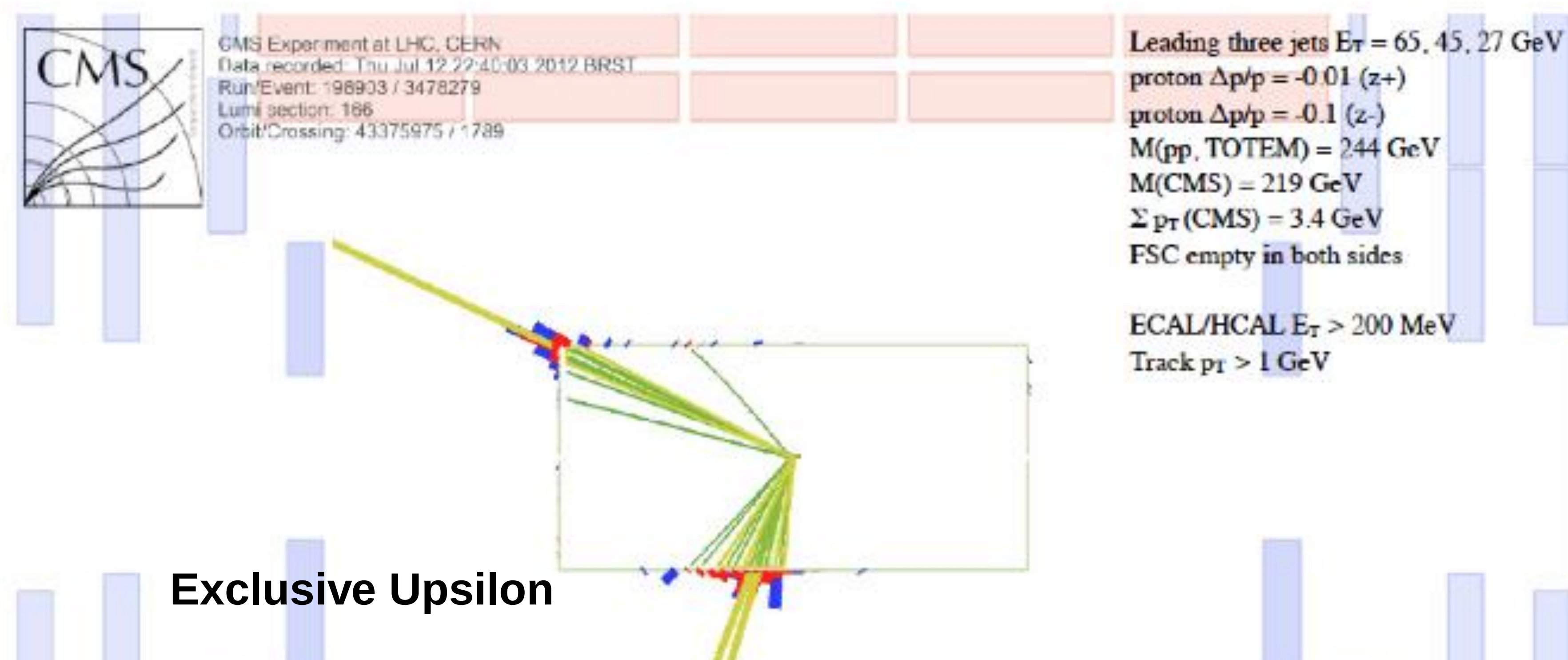
$|t| = p_T^2$ [GeV^2]

Upsilon cross section vs $\sqrt{S}_{\gamma p}$

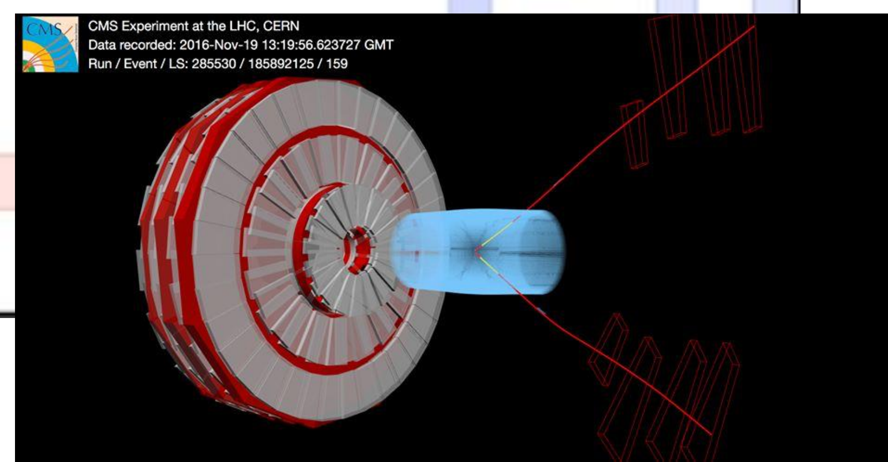


CMS-HIN-15-001

Coming soon: Dijets, Υ …



Exclusive Upsilon



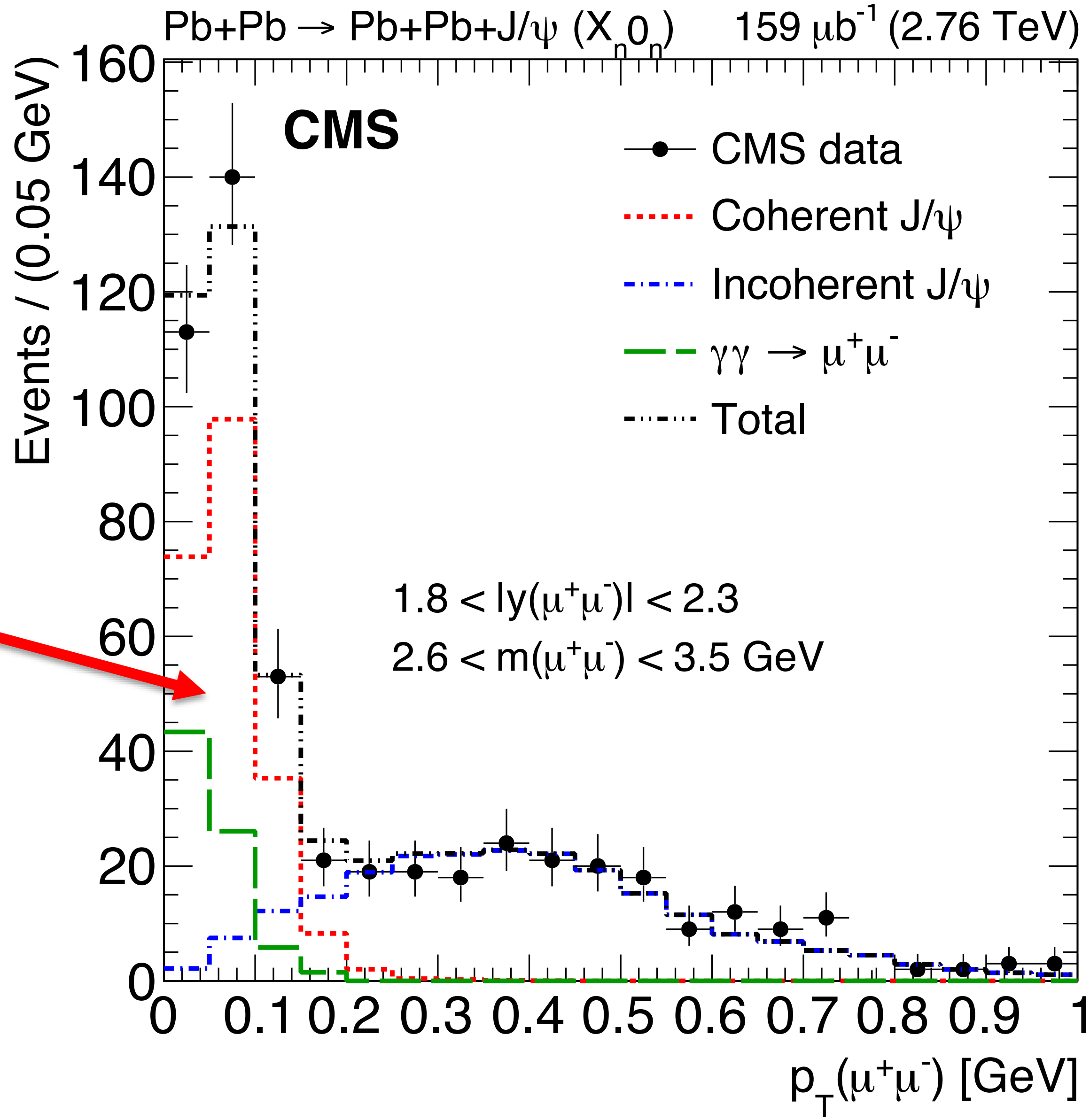
Conclusions

- **UPC γ+Pb => J/ψ suggests that there is significant shadowing of gluons in Pb nuclei at low x and Q^2**
- **Break-up ratios are consistent with theoretical models using multiple photon exchange. Neutron tags can resolve photon direction for forward J/ψ**
- **Incoherent J/ψ are generally emmitted with neutrons in same rapidity hemisphere (high-x component). In qualitative agreement with ALICE results on exclusive J/ψ in γ+p**
- **Cross section for γ+p => Y increases as a power law of center of mass energy**

Backup

Exclusive PbPb => J/ψ + n

CMS-HIN-12-009



Coherent photons have p_T ~ h/R

Outline

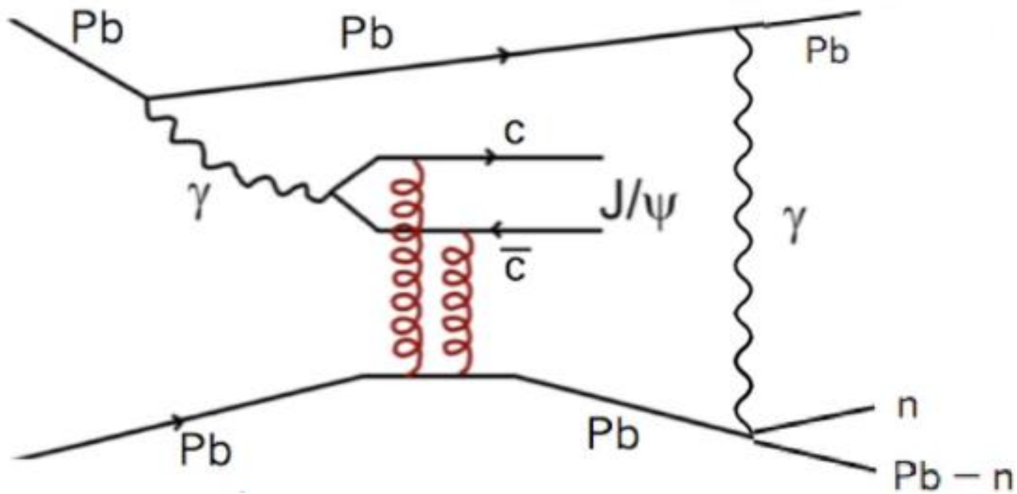
- **Quarkonia production in exclusive γ+p and γ+Pb**
- **Look for effects of gluon saturation**
- **Using neutrons as a photon tag**

Incoherent photoproduction in Pb-Pb

Total cross section

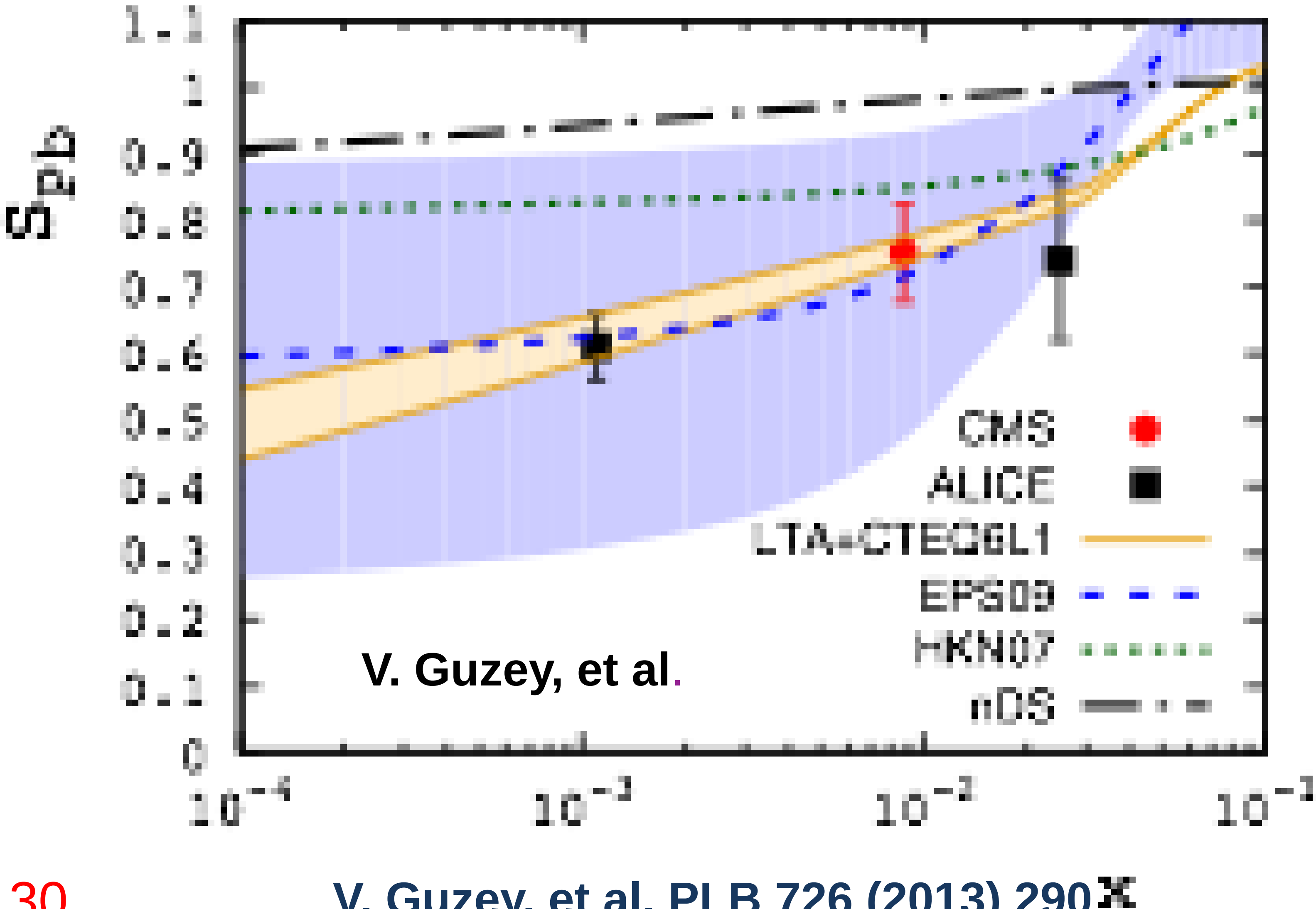
Low W: x~ 10-2 **High W: x~ 10-4**

$$\frac{d\sigma_{\mathrm{PbPb}}(y)}{dy} = N_{\gamma/\mathrm{Pb}}(y, M)\sigma_{\gamma\mathrm{Pb}}(y) + N_{\gamma/\mathrm{Pb}}(-y, M)\sigma_{\gamma\mathrm{Pb}}(-y)$$



Incoherent production is expected to be more sensitive to the photon direction (energy dependence). Here 0nXn and Xn0n will unfold the two x-values

Nuclear suppression factor in Pb



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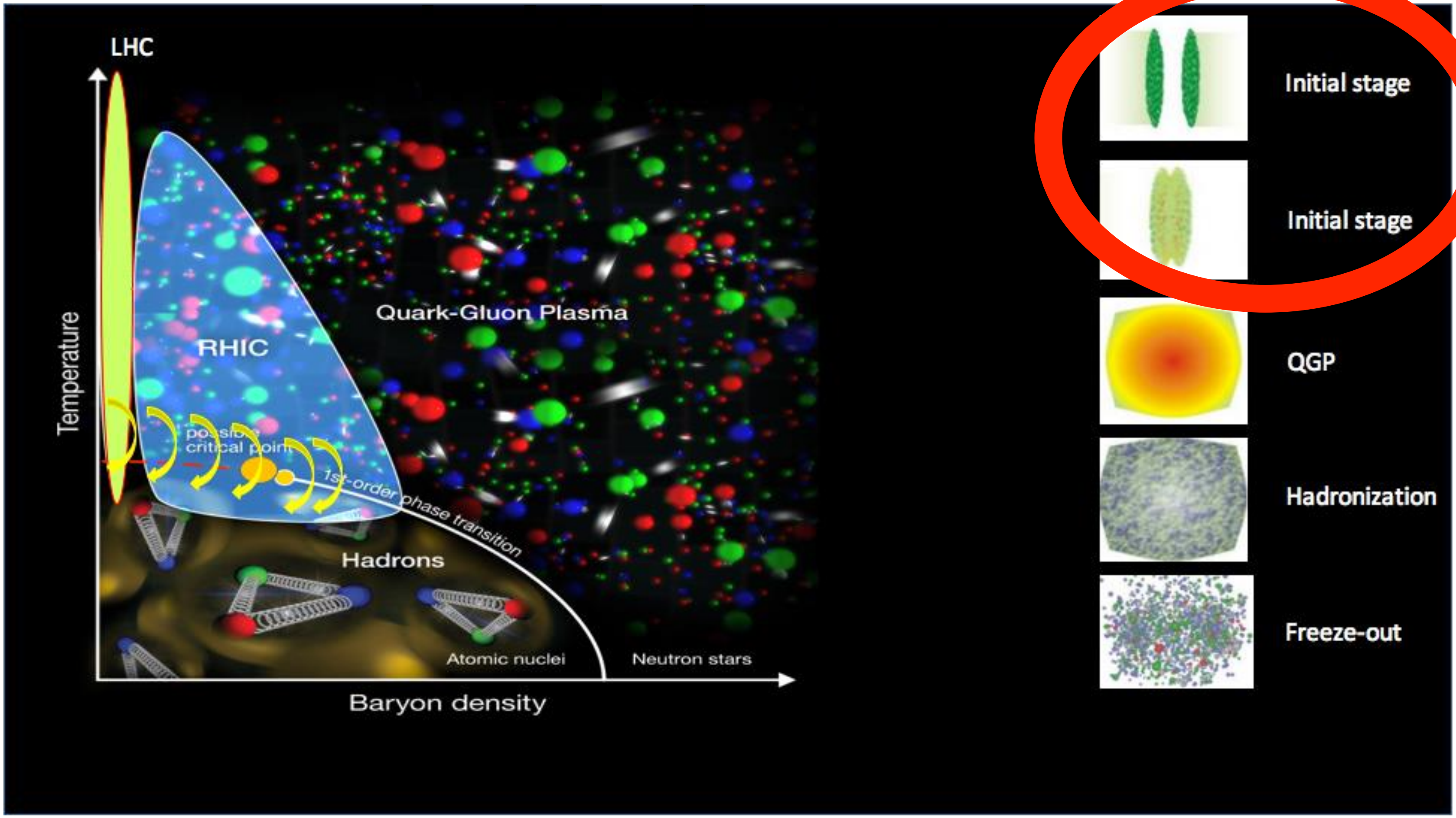
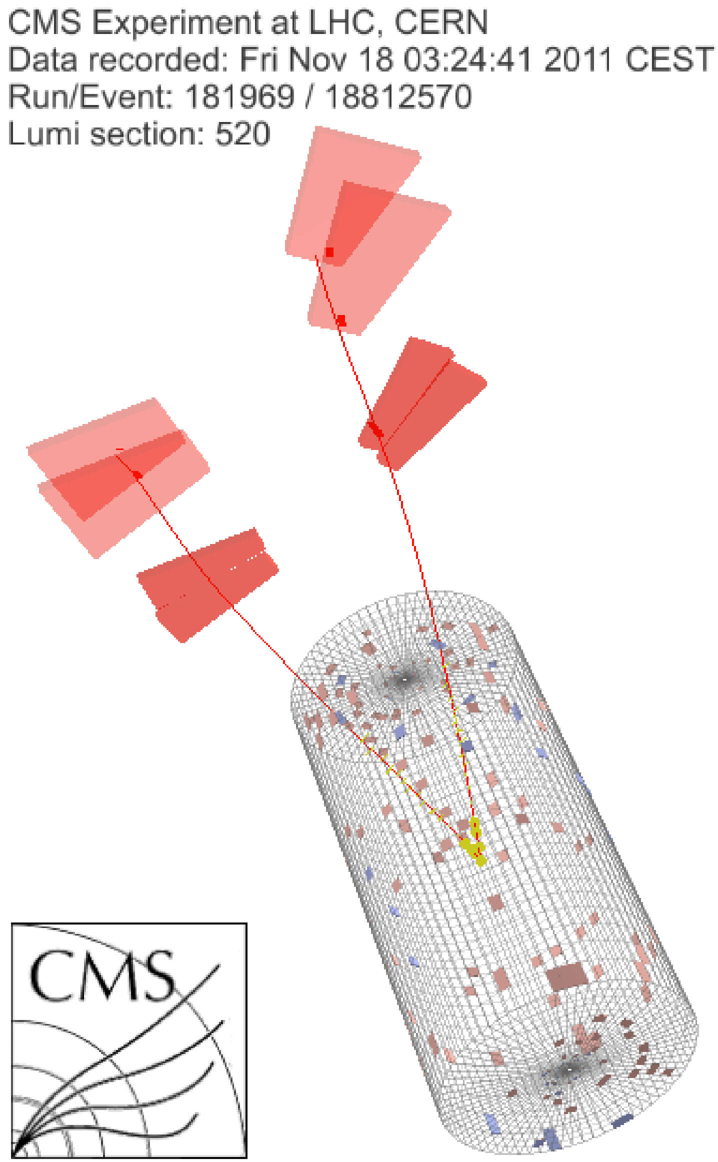
Understanding the

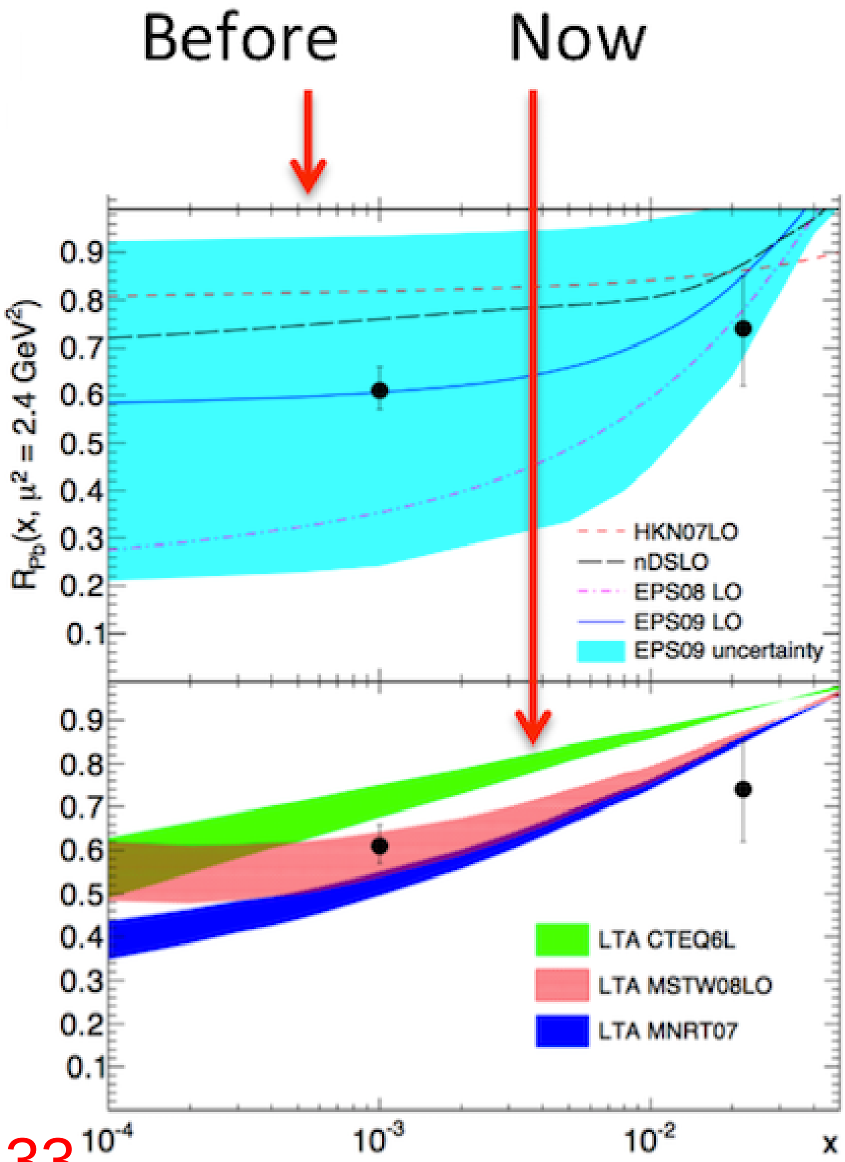


the nature of the initial state is one of the most important questions in high-energy nuclear physics

Coherent J/ψ photoproduction in



Nuclear gluon density



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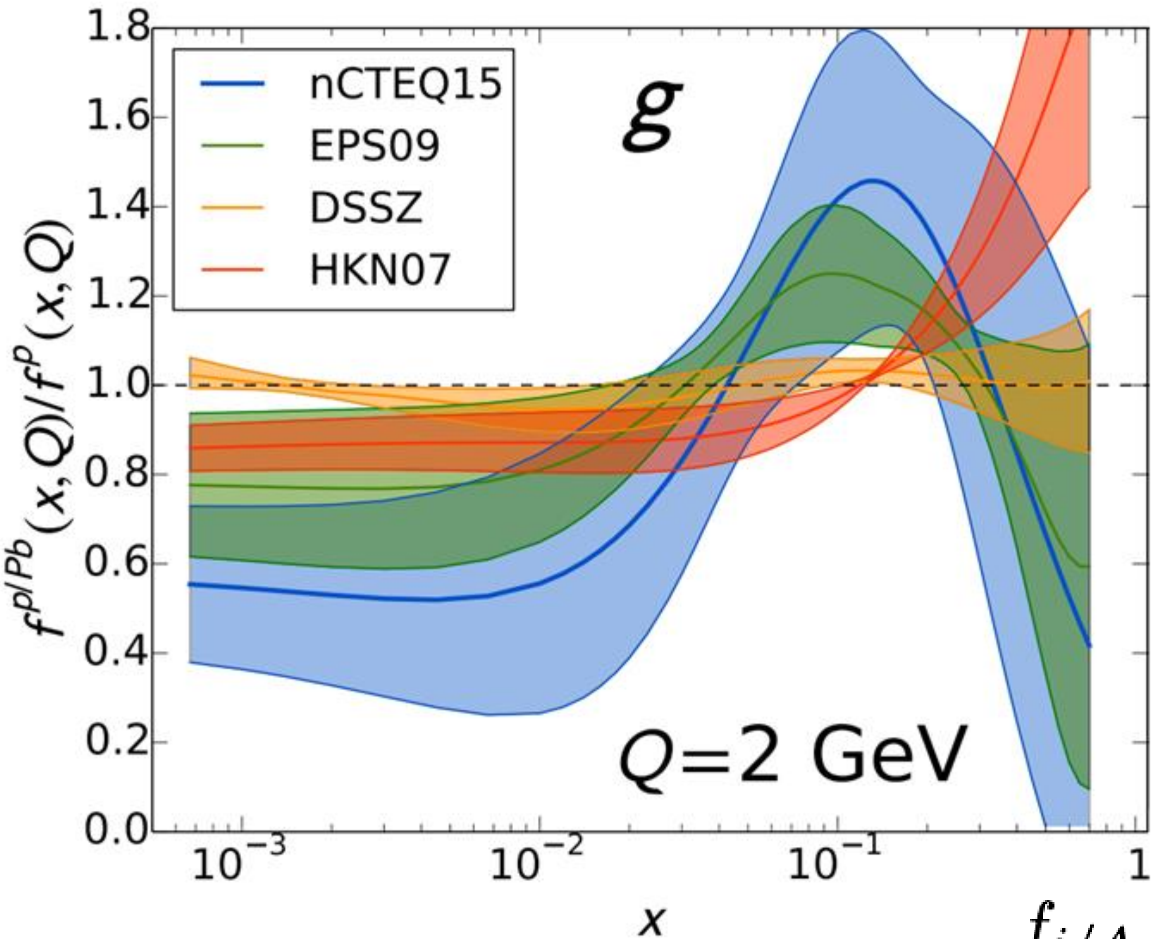
$$S_A(W_{\gamma p}) = \frac{G_A(x,\mu^2)}{AG_N(x,\mu^2)} = 0.61$$

For x ~10^{-3} and Q^2 = 3 GeV^2

Nuclear gluon densites



$$R = \frac{f_{i/A}}{A f_{i/p}} \approx \frac{\text{measured}}{\text{expected if no nuclear effects}}$$